

in the area in which the rate of change of magnetization exhibits the local maximum as the external magnetic field is lowered. In the residual magnetization state, the thermal stability of the magnetization of the recording layer is improved owing to the exchange coupling force as described above. Further, a minor hysteresis loop as shown in Fig. 4 may be observed in the area in which the rate of change of magnetization is locally maximized. The minor hysteresis loop is shown in Fig. 5A. The exchange coupling magnetic field H_{ex} , which is determined from the central point of the minor hysteresis loop, is increased in accordance with the increase of the exchange coupling force between the ferromagnetic atom-rich layer (or the lattice spacing-adjusting layer) and the recording layer. Therefore, it is indicated that the larger the exchange coupling magnetic field is, the larger the thermal stability is. The exchange coupling magnetic field H_{ex} is not less than 1 kOe, preferably not less than 1.5 kOe, which is remarkably larger than that of the conventional type magnetic recording medium shown in Fig. 18. Therefore, it is appreciated that the magnetic recording medium of the present invention is excellent in thermal stability.

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[Page 36, lines 1-2, delete current paragraph and insert therefor:]

Fig. 18 shows a sectional view illustrating a structure of a conventional magnetic disk.

REMARKS

Claims 1-31 are pending in this application.

By this Preliminary Amendment, Applicants amend Figures 12 and 13, and add new Figure 18. Further, the specification is amended to correspond to new Figure 18. New Fig. 18 and its description in the specification were disclosed in the original application and then canceled in the January 25, 2002 Amendment. Thus, the addition of Figure 18 does not raise any issue of new matter because the subject matter of Figure 18 is adequately described in the specification, and is well known to one skilled in the art.

In response to the Election of Species Requirement mailed on January 10, 2003, Applicants hereby elect Species I, claims 1-13, 24, 26, 28, 29 and 31. This election is made with traverse.

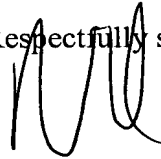
It is respectfully submitted that the subject matter of all claims 1-31 is sufficiently related that a thorough search for the subject matter of any one group of claims would necessarily encompass a search for the subject matter of the remaining claims. Thus, it is respectfully submitted that the search and examination of the entire application could be performed without serious burden. M.P.E.P §803 clearly states that "[i]f the search and examination of the entire application can be made without serious burden, the Examiner must examine it on its merits, even though it includes claims to distinct or independent inventions" (emphasis added). It is respectfully submitted that this policy should apply in the present application in order to avoid unnecessary delay and expense to Applicants and duplicative examination by the Patent Office.

The Examiner is respectfully requested to reconsider and withdraw the Election of Species Requirement and to examine all claims in this application.

In view of the foregoing, Applicants submit that this application is in a condition for allowance. Favorable consideration and prompt allowance of the claims are earnestly solicited.

Should the Examiner believe that anything further is desired to place this application in better condition for allowance, the Examiner is invited to contact Applicants' attorney at the telephone number listed below.

Respectfully submitted,



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Attachment:
Appendix

Date: February 10, 2003

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<p>DEPOSIT ACCOUNT USE AUTHORIZATION Please grant any extension necessary for entry; Charge any fee due to our Deposit Account No. 15-0461</p>
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APPENDIX

Changes to Specification:

The following is a marked-up version of the amended paragraphs:

[0005] The known technique for improving the thermal stability of the magnetic disk, especially a magnetic disk having magnetization in the in-plane direction include a method in which a so-called keeper layer having soft magnetization is provided as an underlying base layer for a recording layer, and a method in which a layer having magnetization in a direction opposite to that of magnetization of a recording layer is provided. As one of the latter method, a technique is disclosed in a literature of E. N. Abarra et al. (E. N. Abarra et al., TECHNICAL REPORT OF IEICE. MR2000-34 (2000-10)) as shown in Fig. 18, in which the thermal stability is improved by forming an Ru thin film as a magnetic coupling layer between a recording layer of CoCrPtB and a magnetization-stabilizing layer of CoCrPtB of a magnetic disk. In the structure of the magnetic disk shown in Fig. 18, when the Ru layer having a thickness of about 0.5 to 1 nm is allowed to intervene as the magnetic coupling layer between the recording layer and the magnetization-stabilizing layer, the exchange coupling is effected in an antiferromagnetic manner between the recording layer and the magnetization-stabilizing layer. Therefore, the layers have antiparallel magnetization, and hence the magnetization of the recording layer is stabilized by the magnetization-stabilizing layer. It is described in this literature that the antiferromagnetic exchange coupling effected by the Ru layer further thermally stabilizes the magnetization of the recording layer, making it possible to improve the recording and reproduction characteristics of the magnetic disk.

[0012] As a result of repeated investigations performed by the present inventors in order to further improve the magnetic disk having the conventional type structure shown in Fig. 18, it has been found out that the exchange coupling force, which is generated between

the ferromagnetic atom-rich layer and the recording layer, is remarkably raised by forming the ferromagnetic atom-rich layer formed with the material having the high ferromagnetic atom concentration as compared with the ferromagnetic material for forming the recording layer, in place of the magnetization-stabilizing layer. The exchange coupling force, which is generated between the ferromagnetic atom-rich layer and the recording layer as described above, is larger than the exchange coupling force which acts between the recording layer and the magnetization-stabilizing layer of the magnetic disk having the conventional type structure shown in Fig. 18. As described above, the strong exchange coupling force is generated between the recording layer and the ferromagnetic atom-rich layer, and hence it is possible to stabilize the magnetization of the recording layer. Therefore, the thermal stability of the recording layer is further enhanced as compared with the conventional magnetic disk shown in Fig. 18, making it possible to realize further advanced high density recording. In the present invention, the term "ferromagnetic atom" means the element which exhibits the ferromagnetic property in the form of simple substance. Specifically, the ferromagnetic atom includes cobalt (Co), nickel (Ni), and iron (Fe).

[0013] The ferromagnetic atom-rich layer is formed with the ferromagnetic material which has the high ferromagnetic atom concentration as compared with the ferromagnetic material for forming the recording layer. For example, when the recording layer is formed of a ferromagnetic material containing Co, Ni, or Fe, the ferromagnetic atom-rich layer can be formed of a ferromagnetic material containing a ferromagnetic atom such as Co, Ni, and Fe at a higher concentration as compared with the recording layer. The ferromagnetic atom-rich layer can be also formed of a metal simple substance such as Co, Ni, and Fe or CoNiFe alloy. Alternatively, the ferromagnetic atom-rich layer may be formed of an alloy containing a transition metal and Co, Ni, or Fe. In this case, the transition metal may be a noble metal such as Pt, Au, Ag, Cu, and Pd. In the present invention, when the ferromagnetic atom

concentration of the ferromagnetic material for constructing the ferromagnetic atom-rich layer is higher than the ferromagnetic atom concentration of the magnetic material for constructing the recording layer, it is possible to obtain the effect to enhance the exchange coupling force generated between the ferromagnetic atom-rich layer and the recording layer. However, in order to obtain a sufficient effect in view of the results obtained in the embodiments as described later on, it is desirable that the ferromagnetic atom concentration of the ferromagnetic material for constructing the ferromagnetic atom-rich layer is higher than the ferromagnetic atom concentration of the ferromagnetic material for constructing the recording layer by not less than 19 % as represented by an absolute value. Especially, it is desirable that the ferromagnetic atom concentration of the ferromagnetic atom-rich layer is 100 %. Owing to the ferromagnetic atom-rich layer as described above, the exchange coupling force, which is generated between the ferromagnetic atom-rich layer and the recording layer, is larger than the exchange coupling force which is generated between the magnetization-stabilizing layer and the recording layer of the conventional magnetic disk shown in Fig. 18. Therefore, the thermal stability of the recording layer is further enhanced as compared with the conventional technique, making it possible to realize further advanced high density recording.

[0016] As a result of investigations performed by the present inventors, it has been found out that the exchange coupling between the recording layer and the magnetization-stabilizing layer can be remarkably improved by intervening a several-atoms-layered Co layer at an interface between the Ru layer (non-magnetic layer) and the recording layer and/or an interface between the Ru layer (non-magnetic layer) and the magnetization-stabilizing layer of the magnetic disk having the conventional type structure shown in Fig. 18. The layer to be intervened at the interface is not limited to Co, which may be composed of a material having a high ferromagnetic atom concentration as compared with the recording layer, and

which may be constructed with a variety of substances capable of improving the exchange coupling between the recording layer and the magnetization-stabilizing layer as described later on. That is, when the magnetic recording medium is provided with the magnetization-stabilizing layer, the exchange coupling force between the recording layer and the magnetization-stabilizing layer can be improved by positioning the ferromagnetic atom-rich layer at the interface. In this specification, the ferromagnetic atom-rich layer is also referred to as "enhancing layer", because the ferromagnetic atom-rich layer is also provided with the function to enhance the exchange coupling between the recording layer and the magnetization-stabilizing layer when the magnetization-stabilizing layer is provided.

[0017] According to the knowledge of the present inventors, the reason why the ferromagnetic atom-rich layer, i.e., the enhancing layer, which is positioned between the magnetization-stabilizing layer and the recording layer, successfully improves the exchange coupling between the recording layer and the magnetization-stabilizing layer is as follows. In the case of the conventional type magnetic disk shown in Fig. 18, the recording layer of CoCrPtB and the magnetization-stabilizing layer of CoCrPtB are stacked with the Ru layer intervening therebetween. In this case, the recording layer and the magnetization-stabilizing layer effect the exchange coupling via the Ru atom layer. It is considered that the exchange coupling is effected on the basis of the fact that the electron orbits are coupled between the Co atoms in the recording layer and the magnetization-stabilizing layer via the Ru atoms. Such a coupling is also found, for example, in the coupling in an artificial lattice of a GMR head.

[0030] The magnetic recording medium of the present invention comprises the lattice spacing-adjusting layer which is formed between the underlying base layer and the recording layer and which is formed of the ferromagnetic material to make control so that the difference in lattice spacing between the lattice spacing-adjusting layer and the underlying

base layer is smaller than the difference in lattice spacing between the recording layer and the underlying base layer. The lattice spacing-adjusting layer as described above mitigates the lattice strain between the underlying base layer and the recording layer, and the crystalline orientation of the recording layer is improved thereby. Accordingly, it is possible to increase the coercive force of the recording layer. The magnetic recording medium as described above is formed of the ferromagnetic material in the same manner as the magnetization-stabilizing layer of the in-plane magnetic recording medium having the conventional type structure shown in Fig. 18. Therefore, it is possible to stabilize the magnetization of the recording layer. That is, the lattice spacing-adjusting layer has a function to stabilize the magnetization of the recording layer, in addition to a function as a seed layer to act so that the lattice strain between the underlying base layer and the recording layer, i.e., the discrepancy of lattice spacing is mitigated. Therefore, the high density recording can be put into practice by using the magnetic recording medium of the present invention, because the minute magnetic domain formed in the recording layer can be stably retained. In the present invention, the term "lattice spacing" means the lattice spacing on the orientation plane.

[0035] It is desirable for the magnetic recording medium according to the second aspect of the present invention that a relationship of $M_{s1} > M_{s2}$ is satisfied provided that saturation magnetization of the lattice spacing-adjusting layer is represented by M_{s1} , and saturation magnetization of the recording layer is represented by M_{s2} . For this purpose, it is desirable that the lattice spacing-adjusting layer is formed so that a ratio of magnetic atom contained in the lattice spacing-adjusting layer is larger than a ratio of magnetic atom contained in the recording layer. Accordingly, it is possible to further increase the exchange coupling force between the recording layer and the lattice spacing-adjusting layer. In the case of the conventional type medium shown in Fig. 18, the recording layer and the magnetization-stabilizing layer are composed of the same material, in which the composition

and the crystal structure are also the same. The recording layer and the magnetization-stabilizing layer are subjected to exchange coupling via the Ru layer. It is considered that the exchange coupling is based on the fact that the electron orbits are coupled to one another for the Co atoms in the recording layer and the magnetization-stabilizing layer by the aid of the Ru atoms. In the present invention, the ratio of the magnetic element in the lattice spacing-adjusting layer is made higher than the ratio of the magnetic element in the recording layer to increase the amount of magnetic element which contributes to the exchange coupling.

Therefore, the exchange coupling force between the recording layer and the lattice spacing-adjusting layer is increased as compared with the exchange coupling force between the recording layer and the magnetization-stabilizing layer of the conventional type medium shown in Fig. 18. Accordingly, it is possible to improve the thermal stability as compared with the conventional type medium shown in Fig. 18.

[0043] Each of the magnetic recording media according to the first and second aspects of the present invention has a magnetic characteristic which is represented by a hysteresis loop as depicted by a magnetization curve as shown in Figs. 4 and 16. The following description will be made on the basis of a case of the magnetic recording medium according to the first aspect. However, an equivalent relationship is also affirmed between the lattice spacing-adjusting layer and the recording layer of the magnetic recording medium according to the second aspect. In the hysteresis loop shown in Fig. 4, a point, at which a rate of change of magnetization with respect to the external magnetic field exhibits a local maximum when the external magnetic field is lowered after magnetization of the magnetic recording medium is saturated, exists in an area of positive magnetic field. When the magnetization of the magnetic recording medium is saturated, both of the magnetizations of the recording layer and the ferromagnetic atom-rich layer (or the lattice spacing-adjusting layer) are parallel. The magnetization of the ferromagnetic atom-rich layer (or the lattice

spacing-adjusting layer) is inverted due to the exchange coupling force exerted between the ferromagnetic atom-rich layer (or the lattice spacing-adjusting layer) and the recording layer in the area in which the rate of change of magnetization exhibits the local maximum as the external magnetic field is lowered. In the residual magnetization state, the thermal stability of the magnetization of the recording layer is improved owing to the exchange coupling force as described above. Further, a minor hysteresis loop as shown in Fig. 4 may be observed in the area in which the rate of change of magnetization is locally maximized. The minor hysteresis loop is shown in Fig. 5A. The exchange coupling magnetic field H_{ex} , which is determined from the central point of the minor hysteresis loop, is increased in accordance with the increase of the exchange coupling force between the ferromagnetic atom-rich layer (or the lattice spacing-adjusting layer) and the recording layer. Therefore, it is indicated that the larger the exchange coupling magnetic field is, the larger the thermal stability is. The exchange coupling magnetic field H_{ex} is not less than 1 kOe, preferably not less than 1.5 kOe, which is remarkably larger than that of the conventional type magnetic recording medium shown in Fig. 18. Therefore, it is appreciated that the magnetic recording medium of the present invention is excellent in thermal stability.

Page 36, lines 1-2:

Fig. 18 shows a sectional view illustrating a structure of a conventional magnetic disk.